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ITS CHARACTERISTICS AND GERMINATION

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Balsam fir (Abies balsamea (L.) Mill.) has become an increasingly important source of pulpwood in the Lake States. Whereas 20 years ago the pulp mills in this region used about 148 thousand cords of balsam fir, in 1946 they used 378 thousand cords of this species. With the constantly decreasing supplies of spruce, long the favored pulping species, balsam fir has consequently assumed new importance.

Because of growing difficulties (both legal and economic) of pulpwood importations, many Lake States pulp mills have been buying forest land so that they could grow at least a part of their wood requirements. Much of this land, however, needs reforestation to bring it to high productivity. Because it makes high-quality pulp, grows rapidly, and is the native conifer best able to withstand brush competition, balsam fir seems to be a good species to plant or seed on many of these areas. The drawback is that this tree species has been little used for planting, and we do not know a great deal about its seed, nursery, or planting characteristics.

Very little has been published on the characteristics and germination behavior of balsam fir seed. Yet these must be well understood before large-scale reforestation plans with this species can be carried out. For this reason, available published information on balsam seed has been brought together, including the results of unpublished studies carried on in the seed laboratory of the Lake States Forest Experiment Station, and will be presented in this paper.

Seed Characteristics

Balsam fir seed is of medium size, more or less brown in color, and roughly quadrangular in shape. It is enclosed on three of its four surfaces by the generally purplish base of a rather large wing. The seed coat is soft and has three or more resin vesicles on its surface, which give it a pronounced resinous odor. The seed, like that of all true

1/ Maintained at University Farm, St. Paul 1, Minnesota, in cooperation with the University of Minnesota.

firs, is borne in pairs at the base of the scales of erect cones, characteristically purple in color, which begin to fall apart on the trees soon after maturity. Dispersal in northern Minnesota usually begins in early September and is at its height during the latter part of that month, with some seed falling during the winter months (8). Seed collection must be done before the cone scales begin to separate. Cones may be collected from the tops of recently felled trees on logging operations or gathered from squirrel hoards. They should be examined to see that the seed is firm and fully mature. Sometimes cones may be picked from standing trees, but this is difficult because they are almost always at the tops of the trees.

Unless the cones are beginning to disintegrate they must be spread out to dry in shallow layers to prevent heating and molding. As they cure the cones break up. The seeds may then be separated from the scales by screening or running through a fanning mill. Commercial balsam fir seed usually isdewinged, but this process as ordinarily carried out seems to be injurious to the soft seed. Most commercial seed germinates poorly, whereas that which has been dewinged by hand-rubbing shows excellent germination. No methods known are effective in removing the more or less persistent wing bases that enclose the seed.

After brief drying the seed either can be used immediately or put into storage. Balsam cones will produce 2.3 to 2.6 pounds of clean seed per bushel. A bushel of clean seed weighs 35 pounds. 2/ Cost of commercial seed has run from

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2/ Richardson, A. H. 1935 (?). Unpublished data on collection, extraction and cleaning of tree seed. Ontario Department of Lands and Forests, Toronto.

$2.75 prior to World War II to $3.50 per pound at the present time.

Published information on purity, seed size, and soundness combined with information obtained by the Lake States Forest Experiment Station shows that commercial balsam fir seed is of high average purity (table 1). All samples tested by American investigators are much cleaner than those tested for the Danish seedhouse of J. Rafn and Son. There is considerable variation in seed size of this species, ranging from relatively large seed (30,000 per pound) reported by Toumey and Stevens (10) to small seed (94,500) of Heit and Eliason (5). Averaging about 59,000 seeds per pound, it is one of the heaviest of our northern coniferous seeds, only white pine and red pine being heavier. Soundness averages rather low. One reason may be that the persistent wing base makes it impossible to fan out all of the empty and abortive seeds.

Table 1. Purity, Number Per Pound and Soundness of Commercial Balsam Fir Seed

Purity			Basis,	No. clean seeds per lb. pure seed			Basis,	Soundness			Basis,	Source
Low	High	Average	Samples	Low	High	Average	Samples	Low	High	Average	Samples	
Pct.	Pct.	Pct.	No.	No.	No.	No.	No.	Pct.	Pct.	Pct.	No.	
-	-	-	-	-	-	44,000	1	-	-	-	-	Chittenden (2)
88	98	95	11	48,000	94,500	68,500	11	-	-	55	11	Heit and Eliason (5)
-	-	-	-	-	-	50,000	1	-	-	-	-	Pettis (6)
42	97	76	13	44,000	78,000	59,200	13	-	-	-	-	Rafn (7)
-	-	-	-	-	-	77,000	1	-	-	-	-	Richardson 1/
-	-	-	-	-	-	35,000	1	-	-	-	-	Tillotson (9)
86	100	96	21	30,000	78,900	56,250	21	5	94	46	21	Toumey and Stevens (10)
-	-	-	-	-	-	36,000	1	-	-	-	-	Zon (11)
77	97	91	7	48,700	82,000	65,900	7	47	78	62	5	Lake States Forest Experiment Station
42	100	90	52	30,000	94,500	59,800	57	5	94	51	37	All Sources

1/ See text, footnote 2.

Seed Storage

No comprehensive tests to determine the proper method of storing balsam fir seed are known. Seed stored in unsealed jars at room temperature for a year lost practically all of its germination (10), but that stored in a sealed jar at 36° to 39° F. showed no appreciable loss in vitality at the end of five years (5). This has been corroborated at the Lake States Forest Experiment Station. Two lots of balsam seed placed in sealed containers at 41° F. in 1939 and 1940 gave excellent germination in 1946. Therefore, until a better method has been worked out, it would seem best to store the seed at a temperature as close to freezing as economically feasible and sealed against changes in moisture content.

What the initial moisture content should be is not definitely known. However, since seed of grand fir (Abies grandis) showed half of its original germination after 11 years of storage at 40° F. and a moisture content of about 6 percent, 3/

3/ Barton, L. V. 1941. Correspondence in files of Lake States Forest Experiment Station.

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it seems likely that balsam seed should be stored with a relatively low moisture content.

Germination Behavior

In nature, germination of balsam fir seed occurs in the spring (late May-June in Minnesota) after the seeds have laidon the ground over winter in a moist, cold condition. In the laboratory, behavior both of freshly collected and of stored seed is variable. Tests of American and Danish-grown seed in standard germinators show that a rather high percentage of the viable seeds will germinate within the first month, some more during the second month, and a few not at all (5, 7). On the other hand, sand-flat tests made under controlled conditions at the Lake States Forest Experiment Station have given very poor germination unless the seed was stratified--sometimes for a long period. In other words, such seed showed pronounced dormancy. However, in the germinator tests the seed was more or less exposed to light, while in the sand tests it was covered with 1/4 inch of sand.

Since some lots of Scotch pine seed show definite dormancy when sown in sand but are not dormant in germinators (4), it seems plausible that balsam seed may also be of this type. Further weight is given this possibility by a field study 4/in which it was found that balsam seed pressed

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4/ Le Barron, R. K. 1940. Unpublished data on germination of balsam seed under field conditions. In files of Lake States Forest Experiment Station.

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lightly into mineral soil and partly exposed to light gave 50 percent germination 5/ compared to 6 percent for similar

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5/ That untreated balsam seed sown lightly covered in the spring will show fair germination the first summer has also been noted by Mr. John Fritzen of the Minnesota Forest Service.

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seed fully covered in the nursery. A laboratory test of the same seed lot made in sand flats earlier that year also showed pronounced dormancy.

Apparently light so influences germination of balsam fir seed that surface sowing might be expected to provide prompt seedling emergence. However, practical field experiments are needed to test this lead. Until it is definitely known how generally this effect occurs, it may be best to continue sowing the seed as in the past by completely covering it. Since sand flat tests in the laboratory show that covered seed is dormant, seed similarly covered in the nursery should also be considered dormant and treated accordingly.

Treatment to Overcome Dormancy

Dormancy in balsam seed to be sown in the nursery can be overcome by fall-sowing or by stratification prior to spring seeding. Soaking in cold water also is beneficial although it is not as effective as prolonged stratification. The optimum stratification conditions have not yet been worked out for this species although a start has been made in that direction.

Prior to 1940 indifferent results had been obtained with balsam seed in the Station's seed laboratory. This was probably due in part to seed of poor quality and in part to improper testing technique. During 1940 tests were begun with two samples of seed, both collected on the Superior National Forest near Ely, Minnesota, one in 1939 and the other in 1940. Both lots were cleaned by screening the cone scales from the seed which was then hand-rubbed to remove the wings. As a result of this careful handling the seed was of high quality, averaging 74 percent in soundness.

Seed of the 1939 lot was cold stratified in moist sand for two different periods and at two different temperatures, and also soaked in running cold water. Germination tests of four subsamples of 200 seeds each were run at three temperatures. The results (table 2) showed that 60 days gave better results than 30 days stratification at 41° F. and that 41° F. was a better stratification temperature than 50° F. Water soaking gave poorer germination than stratification but was better than no treatment. Of the three germination temperatures, daily alternations of 68° to 86° were by far the best. In all tests with this lot, germination was far from complete on the 60th day. It

Table 2. Effect of pretreatment and germination temperature on germination 1/ of balsam fir seed

Pretreatment	Germination Temperature 68-86°F 2/	50-77°F 2/	50°F
	Pct.	Pct.	Pct.
None	3.6	0.6	0.2
Stratify 30 days 50° F	24.4	1.1	0.2
Stratify 30 days 41° F	34.4	5.2	0.6
Stratify 60 days 41° F	47.0	3.8	0.0
Watersoak 2 days 45° F	14.6	0.9	0.2
Average	24.8	2.3	0.2

1/ Germination at 60 days

2/ Lower temperature at night; higher temperature during the day

was therefore clear that the optimum pregermination treatment had not been determined.

Accordingly, another series of tests was begun with the 1940 seed. This consisted of stratification for 30, 60, 90, 120, 180, and 240 days at 41° F. As before each test included 800 seeds. These were germinated at daily alternations of 68° to 86° F. for 60 days; control seed was germinated for 240 days. At the conclusion of the tests the remaining seeds were washed out of the sand to find out how many were still sound.

All stratification periods from 90 to 240 days gave practically complete results in the 60-day period (table 3). Thus there seems to be no advantage in stratifying the seed for 8 months when 3 months gives equally good germination. However, as the stratification period lengthened, the rate of germination increased strikingly (figure 1). Since rapid germination is of prime importance to the nurseryman, it must be concluded that prolonged stratification gave the best results. Obviously these two lots of seed from northern Minnesota had pronounced dormancy, and required prolonged stratification to make them readily germinable.

Balsam fir is a species of the northern forest and thus may possibly have its seed dormancy overcome at a temperature which is somewhat lower than 41° F. which has proven optimum for so many other seeds. At least in nature it seems likely that the seed is exposed to surface temperatures which may average lower than this. Hence it seems possible that the pronounced dormancy shown by this seed might be overcome in the laboratory by stratification at lower temperatures and for shorter periods.

Germination Capacity of Balsam Fir Seed

The germination that the nurseryman can expect from balsam fir seed varies greatly (table 4). Part of the variation doubtless is due to poor seed quality, the result of careless dewinging, improper storage, and the like. At least some of it, however, judging from the rather large amounts of ungerminated living seeds, must be due to the lack of prior pretreatment and the failure to test such seed for a long enough period. It is therefore clear that many of the past tests, especially those made in sand, failed to show the full germination potential of the seed, and this should be taken into account in working out sowing ratios. On the other hand, the high germination obtained with hand-cleaned seed implies that this potential can be considerably increased by better methods of handling during the extraction and cleaning processes.

Nursery Practice

Until the optimum pretreatment has been worked out for this

Table 3. Germination of Balsam Fir Seed After Various Periods of Stratification at 41° F.

Pretreatment	Germinative Energy		Actual Germination			Potential 1/ Germination
	Amount	Period	Amount	Last germination	Test Over	
	Pct.	Days	Pct.	Days	Days	Pct.
None	40	82	47	208	240	47
Stratify 30 days 41° F	51	60	51	60	60	68
Stratify 60 days 41° F	54	43	63	60	60	69
Stratify 90 days 41° F	61	48	70	60	60	71
Stratify 120 days 41° F	67	36	72	60	60	72
Stratify 180 days 41° F	67	26	72	60	60	75
Stratify 240 days 41° F	70	22	2/ 75	59	60	76

1/ Actual germination plus sound ungerminated seeds

2/ 0.5 percent occurred during stratification, beginning at about 223 days

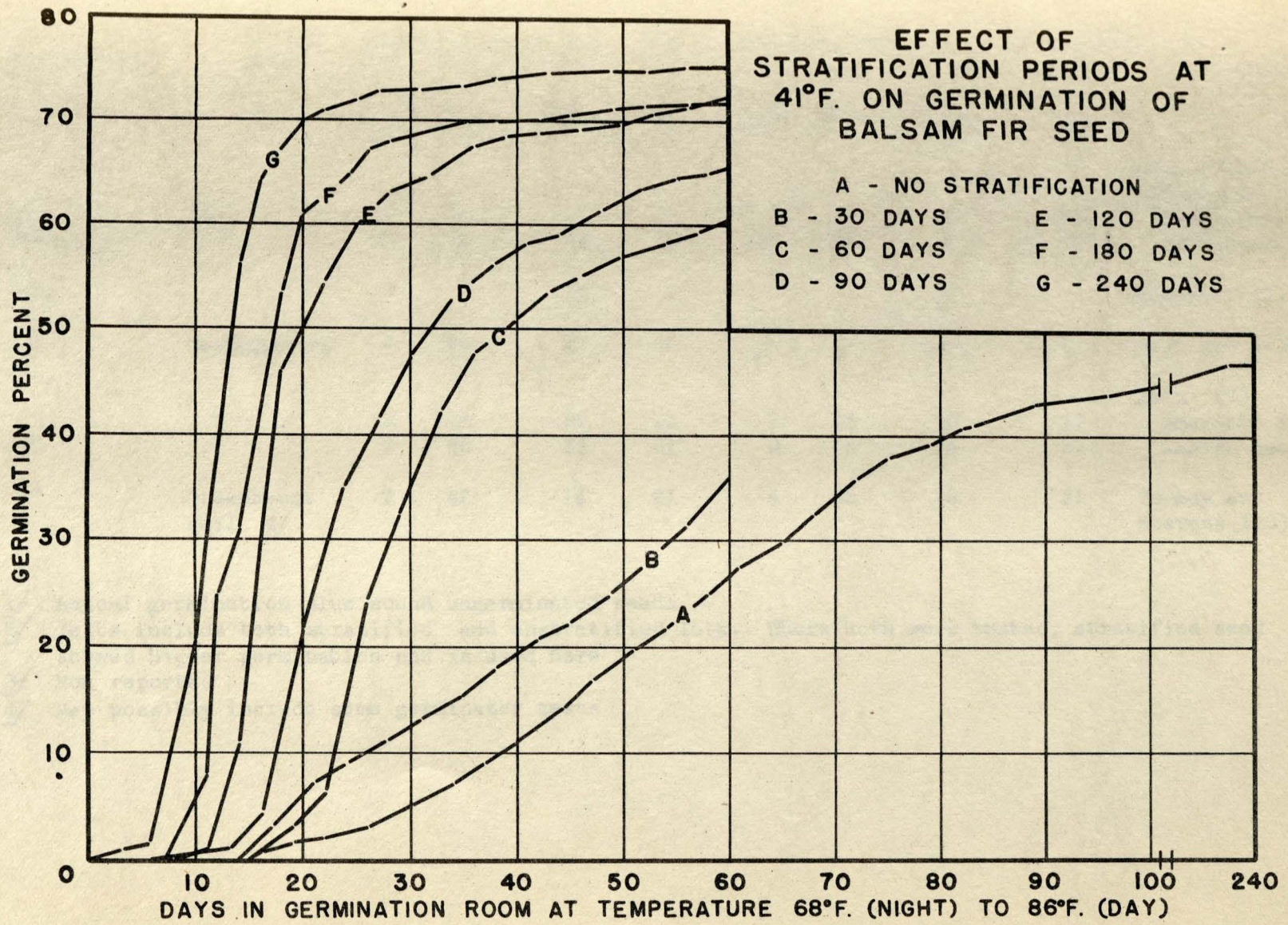
EFFECT OF STRATIFICATION PERIODS AT 41°F. ON GERMINATION OF BALSAM FIR SEED
A - NO STRATIFICATION
B - 30 DAYS
C - 60 DAYS
D - 90 DAYS
E - 120 DAYS
F - 180 DAYS
G - 240 DAYS
GERMINATION PERCENT
0
10
20
30
40
50
60
70
80
10
20
30
40
50
60
70
80
90
100
240
DAYS IN GERMINATION ROOM AT TEMPERATURE 68°F. (NIGHT) TO 86°F. (DAY)

Table 4. Germination of Commercial Balsam Fir Seed

Pretreatment	Testing Media	Actual Germination Low	Actual Germination High	Actual Germination Average	Basis Tests	Potential Germination 1/ Low	Potential Germination 1/ High	Potential Germination 1/ Average	Basis Tests	Source
		Pct.	Pct.	Pct.	No.	Pct.	Pct.	Pct.	No.	
2/	Sand	0	50	15	5	2	50	-	2	Lake States Forest Experiment Station Commercial seed
Stratified	"	73	75	74	2	74	76	75	2	Hand-cleaned seed
None	"			18	1			3/		Boerker (1)
"	Germinators	5	46	27	11	3/	3/	3/		Heit and Eliason (5)
"	"	1	44	25	13	1	54	30	13	Rafn (7) American seed
"	"	9	68	33	21	9	68	34	21	Danish seed
"	Greenhouse soil 4/	2	42	14	21	4	62	25	21	Toumey and Stevens (10)

1/ Actual germination plus sound ungerminated seeds
2/ Tests include both stratified and unstratified lots. Where both were tested, stratified seed showed higher germination and is used here
3/ Not reported
4/ May possibly include some germinator tests

species, it is recommended that the seed be fall-sown. If this is not practicable, the seed should be stratified - - about 6 months to produce rapid germination - - in moist sand (peat would likely be just as satisfactory) at a temperature of 41° F. Such prolonged stratification has given good results at the Eveleth, Minnesota nursery.

The seed should be sown in drills or broadcast to give 60 to 80 seedlings per square foot, and covered with about 1/4 inch of nursery soil. Balsam fir seedlings are subject to damping-off, hence the beds should be treated before seeding with sulphuric acid or aluminum sulphate. Fall-sown beds require mulching over winter, preferably with burlap. Data on nursery germination are meager. One source (9) records 15 percent. Seedlings are subject to heat injury and in northern latitudes should be given half shade the first season. This may also be necessary the second season if it is hot. Reliable data on tree percent are also sparse. The only information available shows 15 to 20 percent survival for the seeding at Eveleth at the end of the second season. Growth is slow, hence stock usually has to be 2-2 transplants before it is large enough for field planting.

Few enemies are known to attack balsam in the nursery. Occasionally the larvae of the pales weevil (Hylobius pales) are said to attack the seedlings in New England. There are also records of defoliation in the Northeast from snow-mold. This disease, caused by species of Phacidium, can be controlled by late-fall spraying with lime sulphur dormant-strength (3).

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